KaBLE-II Experiment on Mars Global Surveyor

Stan Butman

One of the major thrusts of the DSN Technology Program is to allow for and demonstrate the link advantages available from communication at Ka-band (32.0 GHz spacecraft-to-ground). The Mars Global Surveyor (MGS) mission is an opportunity to demonstrate Ka-band deep space communications quickly and at low cost. The mission is willing to host the experiment, and its November, 1996 launch allows us a fast schedule.

There was a Ka-Band Link Experiment (KaBLE) on Mars Observer, but it was limited in two ways. First, the Ka-band signal strength was very low (25 mW compared to the 25-W X-band) In addition, the KaBLE antenna was the 28-cm subreflector on the high-gain antenna (HGA), rather than the 1.5-m main reflector used for the X-band signal, combining for a difference of 37 dB in effective isotropic radiated power (EIRP). Secondly, the signal was obtained by multiplying the frequency of the X-band signal by a factor of four; this changed the modulation index and also created a signal at 33.7 GHz, not quite the DSN Deep Space Ka-band receive frequency.

The Ka-band experiment on MGS, called KaBLE-II, represents a significant step beyond the Mars Observer experiment. Martin Marietta, the builder of the spacecraft communications system, is adding the parts shown in gray in the diagram below. Use of a 1-W Ka-band solid state amplifier and full illumination of the high-gain antenna (HGA) will mean that the Ka-band signal will be only 14 dB weaker than the 25-W X-band traveling-wave tube amplifier (TWTA) signal. Also, the X-band signal will be frequency-translated to 32.0 GHz rather than frequency multiplied, so that the signal in this experiment is now in the Ka-band deep space allocation and has the same mod index as the X-band signal.

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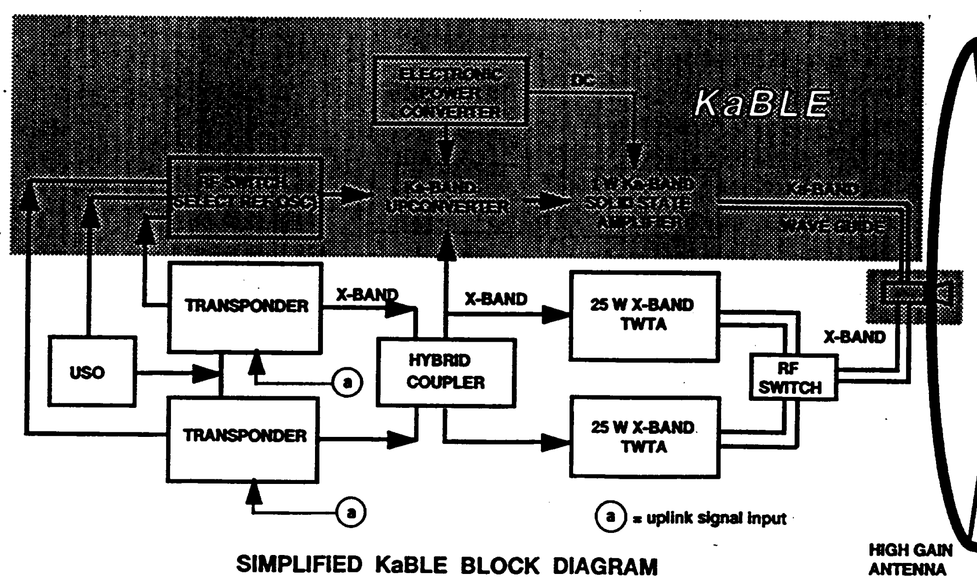

SIMPLIFIED KaBLE BLOCK DIAGRAM
(shows downlink rf path through HGA)

The Ka-band Antenna Performance Experiment

KaAP Ka-BAND ANTENNA PERFORMANCE

David Morabito

The use of Ka-band (32 GHz) for deep space communications is the focus of a major effort in the DSN Technology Program. (See "Ka-Band for Pluto Fast Flyby" in this issue for more on this.) To quantify the link advantage of Ka-band over X-band, we need to evaluate the performance of our beam waveguide (BWG) antennas at Ka-band and at X-band, and to characterize the statistical effects of the atmosphere, which has a larger effect at higher frequencies. Right now, there are no deep space missions transmitting at Ka-band, so these evaluations must be done using natural radio sources (e.g., planets and quasars).

These evaluations will allow us to quantify the advantage of Ka-band relative to X-band, to measure incremental Ka-band BWG performance improvements, and to demonstrate and develop optimal operational strategies for BWG antennas. The information gained will benefit not just the DSN but also future flight projects considering Ka-band. The Ka-Band Antenna Performance Experiment, or KaAP, uses dual frequency observations of natural calibrator radio sources at Ka-band (32 GHz) and X-band (8.4 GHz), to provide estimates of the performance and atmospheric noise at each frequency.

A measure of a station's performance at a frequency is its gain (G) over system temperature (T), or G/T. By comparing the G/T measured at Ka-band to that measured at X-band, we can estimate the link advantage of Ka-band relative to X-band, and compare that advantage with predicted values.

Since the ratio of gains is proportional to the ratio of the frequencies squared, one expects a theoretical increase of a factor of 14.5, or 11.6 dB, in gain at Ka-band over that at X-band. However, less antenna efficiency at Ka-band lowers this gain. At the same time, there is higher atmospheric noise temperature and increased weather susceptibility at Ka-band, raising the system temperature. Thus the gain in G/T will be less than 11.6 dB; we seek to learn how big this can be, and how much it will vary with weather.

Several DSN telecommunication studies have shown that by utilizing Ka-band rather than X-band on a spacecraft-to-ground communications link, an advantage of 6 to 8 dB (factor of 4 to 6 improvement) can be realized for a given spacecraft transmission. The link advantage can be used to increase data volume, decrease transmission time, decrease transmission power on the spacecraft, decrease spacecraft antenna size, or allow a smaller antenna on the ground.

The first Ka-band link experiment to verify the theoretical studies and identify any obstacles that may prevent this link advantage from being realized was carried by Mars Observer. This experiment, known as KaBLE (for Ka-Band Link Experiment), involved acquiring data at DSS 13 from Mars Observer's Ka-band beacon and X-band signal between January and August, 1993.

With the loss of Mars Observer, it became important to continue the study of the link advantage until another spacecraft with Ka-band capability became available. The KaAP Project was initiated to observe natural radio sources at both Ka- and X-band in order to characterize this link advantage at DSS 13, and to characterize the gain or efficiency of the antenna at both bands as various improvements or configuration changes were made.

During a KaAP experiment, a series of observations of radio sources in different parts of the sky are observed over a wide elevation angle range. These experiments are currently conducted twice a month.

KaAP uses dual-frequency observations of natural radio sources at Ka-band and X-band to provide estimates of performance

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Each observation of a radio source involves boresighting the antenna beam across the source in two orthogonal directions while taking temperature measurements using a total power radiometer. A peak temperature due to the source is estimated by fitting an antenna beam model over the temperature measurements. The peak temperatures are converted to estimates of the antenna efficiency using an equation that includes corrections for the radio source's flux strength, its angular flux distribution over the antenna beam, and a loss factor due to atmospheric attenuation (to refer the efficiency measurements to zero atmosphere). In addition to the boresight observations, system calibrations are routinely conducted to correct for gain changes as the experiment progresses.

To increase our knowledge of atmospheric noise, additional observations known as tipping curves are performed, usually at the start or end of an experiment. Here, the antenna steps from zenith to lower elevation angles measuring the cold sky temperatures. From these data, the noise temperatures and loss factors due to the atmosphere are estimated. These measurements are used to characterize the effect of the atmosphere during the data acquisition period, and correct the efficiencies for atmospheric attenuation. The atmospheric noise temperatures extracted from the tipping curve can be compared and correlated with those determined from a model using input surface meteorological data and from water vapor radiometer (WVR) data. The knowledge we gain about the temporal variability of the link advantage due to weather effects will allow planners of future flight projects to develop robust, efficient telecommunication strategies at Ka-band.

Two spacecraft with Ka-band signals are planned to be launched in the next two years. SURFSAT-1, scheduled to launch in September, 1995, is a DSN Technology Program flight experiment that will be described in our next newsletter. Mars Global Surveyor, scheduled to launch in November, 1996, will carry KaBLE-II, another DSN Technology Program experiment described in this newsletter. We will then be able to study the Ka-band link using a spacecraft source, but until then we continue to learn about Ka-band reception through KaAP.

***KaBLE-II* CONTINUED FROM PAGE 4**

The Ka-band signals will be received at the DSN's research antenna (DSS 13), which is equipped for Ka-band. The goals for this experiment include both data gathering for Ka-band systems planning and demonstration. We will demonstrate high-rate Ka-band telemetry, Doppler, and range data acquisition on a deep space link. We will be able to quantify the relative performance of X- and Ka-band telemetry over an extended period, including times of low Sun/Earth/Probe (SEP) angles. (Because 1-cm waves pass more easily through the Sun's Corona than 3.6-cm waves, Ka-band communications should be maintained at much smaller SEP angles than X-band communications. This is one of the expected advantages of Ka-band that we hope KaBLE-II will help us quantify.) And finally, DSN Ka-band implementations for Cassini and New Millenium can be tested with the KaBLE-II signal.

The KaBLE-II experiment is proceeding as planned. The DSN Technology Program has provided funding to MGS to make spacecraft procurements, and the design and building of the parts is taking place at Martin Marietta, which is working hard to meet the launch date. The dual frequency X-/Ka-band breadboard feed is completed, and the X-to-Ka coherent upconverter design is in progress. JPL may help by providing a state-of-the-art 1-W Ka-band solid state power amplifier.